A METHOD OF IDENTIFYING RATIONAL SOLUTIONS FOR THE LOGISTICS OF CONSTRUCTION MATERIAL SUPPLIES FOR EXTENDED MAJOR FACILITIES

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In the context of implementing large-scale construction and reconstruction projects, it is important to approach the choice of suppliers, as well as the method of transportation, transshipment points and storage warehouses with a reasonable approach. Specific decisions should be based on a thorough analysis of information regarding suppliers, the characteristics of the materials being sold, the capacity of the transshipment infrastructure in the vicinity of the construction site, as well as information about the potential location of temporary auxiliary facilities such as temporary storage yards and marinas. The article presents a method for finding rational solutions, based on which a transport and logistics scheme for the supply of extended construction sites with building materials can be created, taking into account their cost, inventory levels of suppliers and the minimum transportation component of 1 ton of cargo at point of consumption. The proposed solutions could be used to develop a logistics system for the supply chain of construction projects, such as highways and railway lines which don't have stable routes for the supply of materials at the construction stage. Classical methods of solving the transport problem cannot be applied in conditions of great variability. Therefore, the solutions proposed in this article are particularly relevant for ranking terms of delivery of various materials (aggregates) from a large number of suppliers. The advantages of the proposed solutions include the ability to perform calculations in any software and computing complex, and the transparency of the description of the calculation methodology allows automating computational processes in any programming language.

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Introduction

As part of the implementation of the national project «Efficient Transport System», work began on the construction of a high-speed railway between Moscow and St. Petersburg. Projects for the development of high-speed railway (HSR) systems on the routes between Moscow, Yekaterinburg, Adler and Minsk are also being considered. Each of these high-speed rail projects involves the construction of dedicated mainlines, the routes of which pass through areas not provided with transport infrastructure.

The extent of a construction site for major infrastructure projects may span tens or even hundreds of kilometers. When devising a strategy for organizing construction operations at such sites, it becomes evident that providing the site with resources is a multifaceted task that requires intricate logistics solutions [1].

It is important to acknowledge that the estimated project costs may vary significantly due to local circumstances in specific sections of the proposed route. These variations are attributable to differences in supply conditions and the significance of transportation costs in the overall price of goods at the construction site [2-5].

With the presence of several suppliers on the market offering construction materials with suitable specifications, as well as a variety of options for choosing the delivery method offered by each supplier, the scope of the task has become so large that it is difficult to solve without the use of computational power from software products.

Therefore, a transport plan should be developed to ensure the delivery of materials to the construction sites along the route in the required quantity, while minimizing transport costs, including costs associated with loading and unloading at transfer points, taking into account the cost of constructing these facilities and ensuring their required capacity [6, 7].

The transport and logistics plan forms the basis for the development of projects for the construction of transshipment facilities for building materials, including temporary cargo yards. It also contains initial information on the volumes of cargo to be handled at each point.

The aim of this paper is to propose methods for the development of a transport and logistics network, considering the minimization of expenses with limited resources provided by suppliers and the transportation infrastructure.

Materials and methods

In the presence of a wide range of methods for optimizing transportation and logistics processes, it is not possible to say that they are universally applicable and can be used absolutely for any construction project within the context of logistics for the provision of construction materials. This is particularly true when considering very extended construction sites. A large number of suppliers use different modes of transportation and options for their use, even on the same route, making it necessary to find a solution for a multi-product network with criteria to minimize total transportation costs within the limitations of suppliers' capabilities and the capacity of transportation communications.

The transport and logistics scheme for the delivery of aggregates should take into account technological processing of goods during transportation, including use of cargo in soil mixing plants [8]. In addition, it is important to be aware of the shipping seasons at points of sale and the potential acceptance of cargo from sea transportation, as the geographic location may imply seasonal restrictions for certain modes of transportation [9-12].

When establishing the standards for the quantity of building materials required per unit of measure of an object, it is essential to determine the distribution of consumption points along its entire length. Each such location can be referred to as a "transshipment point" and is an area that receives cargo and has accessible storage space. Let each transshipment point be represented by the variable «j».

The construction project should be divided into distinct sections (clusters), for which individual conditions should be established in order to provide aggregates. Let each cluster be represented by the variable «k».

It is evident that, when designing logistics plans, it is essential to consider the final specific and total cost of goods at receiving points for highway construction projects.

Before forming a transport and logistics scheme, it is necessary to conduct a preliminary analysis of the sales market. This analysis should include searching for suppliers, conducting laboratory tests on building materials to ensure compliance with certain requirements for building materials and mixtures, determining available supply volumes, obtaining commercial offers, and studying the market for offers from transport companies [13].

Let each supplier selling construction goods (aggregates) with suitable characteristics be represented by the variable «i», and each type of required construction good (aggregate) be represented by variable «g».

Following a comprehensive analysis of the commercial propositions from all suppliers, a structured and consolidated dataset can be generated. Within this consolidated dataset, through the application of sorting and filtration methods for variable values, it becomes possible to establish a catalogue of suppliers for every transshipment point (At the same time, the transshipment point should serve the logistics of road construction.). This catalogue of suppliers is constructed by ranking vendors based on their delivery terms, with the most advantageous conditions being assigned the highest rank and the least favourable conditions receiving the lowest rank, while also taking into account their adherence to stock limits.

Based on the analysis of the data, which will be further discussed in the article, potential combinations of transportation modes and transshipment point for delivery are identified for each supplier. These combinations are represented by the variable «s».

Each unique combination of transportation and transshipment modes between points «i» and «j», is referred to as a «transportation and logistics scheme».

The initial formalization of the problem suggests that a solution may be found by using classical transport problem for the minimization of the cost of goods under an «ex- warehouse» arrangement, which includes the price of the cargo in the sellers' warehouses. Thereafter, trade conditions will use the basic terms of delivery: ex-warehouse, ex-wagon, and ex-route, reflecting the transfer of liability from the seller to the buyer.

In addition to transportation costs, the final cost of goods should also include the costs associated with loading and unloading operations.

The costs associated with all loading and unloading operations along the route, as well as any additional technological processes performed on goods at transfer points, can be calculated using the following equation 1:

$$F = \sum\sum\left(cost_{g,i,j,s} + proc_{g,j} + load_{g,j} + tr_{j,k}\right) * v_{i,j,g,k} \rightarrow min \quad (1)$$

The variable $cost_{g,i,j,s}$ represents the cost of transporting one ton of aggregate «g» from supplier «i» on the basis of the "ex-warehouse" delivery, as well as the cost of transportation to the transshipment point «j» within the logistics scheme «s».

The $proc_{g,j}$ variable denotes the cost associated with additional processing of one ton of cargo «g» at transshipment point «j». These costs may include processes such as sorting, packaging, temporary storage and other cargo handling.

The variable $load_{g,j}$ signifies the expenditure incurred by loading one ton of aggregate «g» into vehicles at transshipment point «j». The parameter value can take different values depending on the equipment at the transshipment point, with transshipment mechanisms (their characteristics and quantity), the operating mode, and other parameters that characterize the cost of cargo operations.

Meanwhile, the variable $tr_{j,k}$ specifies the expense of moving one ton of cargo from transshipment point «j» to cluster «k». This cost may vary depending on the distance, type of transport used and other logistical factors.

The first step in solving the problem is to combine all the data on suppliers and unique combinations of transportation and transshipment points in potential delivery routes. Let's call this data set a Framework.

The most detailed list of possible modes of transportation for the transportation of goods from customers to construction sites along the proposed route should be included in the framework. Also, the framework should include the conditions of technological processing of goods at transshipment points and the possibilities of their storage.

It is advisable to segment the proposed route into construction clusters (k_i), where the transportation of materials will involve uniform operations. We will define a section of a highway as a cluster, which is bounded on either side by large artificial structures, or large artificial structure, or a section with a technological servicing route, or a section with a technological servicing route, or section with the topographic features or design specifications (see Figure 1).

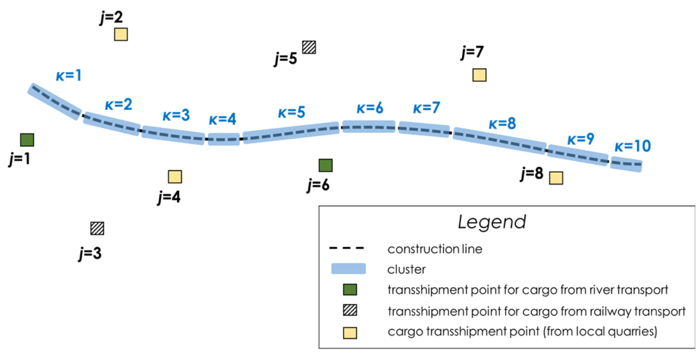

Fig. 1. An example of a transport and technological framework

For designing the framework, it is necessary to take into account the limited capacity of existing transport lines and transshipment points. This also involves processing a certain volume of cargo at mass transfer points, such as producing various mixtures in soil mixing plants and concrete mixers, or separating aggregates into different fractions.

With the introduction of these additional conditions, which create additional restrictions compared to traditional approaches to solving the transportation problem [14], the application of methods such as the potential or northwest corner methods becomes infeasible [15].

Due to the fact that classical methods for solving transportation problem are not applicable, it is necessary to explore potential alternatives involving working with various variables. As a possible approach, the authors suggest considering solving the problem by using linear programming techniques to process initial data matrices. By processing initial matrices and formalizing an optimization objective function, compliance with all relevant conditions and constraints can be ensured and desired outcomes can be achieved [16, 17].

To design the framework for the transport system, symbols for variables are selected, as shown in Table 1.

Table 1

Symbols of variables in the framework of the transport scheme

Variable	The range of accepted values
$i, i \in D$ D – an array of all suppliers	$(1, i_{max})$ i_{max} – total number of suppliers
$s, s \in S$ S – array of various schemes for the delivery of aggregates to transshipment points « j»	$(1, s_{max})$ s_{max} – the maximum number of available schemes for combining different delivery methods between « i» and « j»
$j, j \in J$ J – an array of all transshipment points, the characteristics of which allow them to be included in the calculation of transport schemes	$(1, j_{max})$ j_{max}– total number of transshipment points
$k, k \in K$ K – an array of clusters that are allocated in the area under consideration, taking into account local conditions	$(1, k_{max})$ k_{max} – total number of clusters allocated in the analyzed area
$g, g \in G$ G – an array of all cargo or aggregate nomenclatures required for construction work on the site of the proposed project route	$(1, g_{max})$ g_{max} – total number of cargo or aggregate nomenclatures
$r, r \in R$ R – an array of all types of construction works planned on the analyzed site	$(1, r_{max})$ r_{max} – total number of types of construction works planned on the analyzed site

The creation of a ranked list of schemes for supplying various types of goods or aggregates from each supplier is proposed by filling out the primary matrix of goods costs in the "ex-transshipment point" scheme. The matrix considers all possible suppliers who sell a certain type of cargo or aggregate (building materials). For each supplier, all possible delivery options for each transshipment point «j» are calculated.

The values of the cost-related variables are input into the cost matrix by comparing the data in the primary rows and columns. In this instance, the indicators of parameter $cost_{1,1,2,1}$ suggest the total price of cargo 1 from supplier 1 upon delivery to transshipment point 2 according to delivery scheme 1. Empty cells or cells containing dashes indicate that, according to the specified delivery plan, this cargo cannot be transported by the specified supplier using the current transportation scheme. To illustrate how to populate matrix cells with variables, see Table 2.

Table 2

A matrix of the costs associated with transporting cargo from different suppliers, according to the delivery schemes available for each transshipment point ($mCost$)

g	i	s	j						Compliance
			1	2	3	4	5	6	
1	1	1	$cost_{1,1}$	$cost_{1,1}$	-	$cost_{1,1}$	-	-	1
1	1	2	-	$cost_{1,1}$	$cost_{1,1}$	-	$cost_{1,1}$	-	1
1	2	2	-	$cost_{1,2}$	$cost_{1,2}$	-	$cost_{1,2}$	-	1
1	2	3	-	-	$cost_{1,2}$	$cost_{1,2}$	-	-	1
1	3	2	-	$cost_{1,3}$	$cost_{1,3}$	-	$cost_{1,3}$	-	1
2	3	2	-	$cost_{2,3}$	$cost_{2,3}$	-	$cost_{2,3}$	-	1
2	3	4	$cost_{2,3}$	-	$cost_{2,3}$	-	$cost_{2,3}$	-	1
2	4	1	$cost_{2,4}$	$cost_{2,4}$	-	$cost_{2,4}$	-	-	1
2	4	4	$cost_{2,4}$	-	$cost_{2,4}$	-	$cost_{2,4}$	-	1
2	6	5	-	-	-	-	-	$cost_{2,6}$	1

An additional control parameter, "Compliance", in the form of a binary variable, can be used to regulate the current operation of solving a problem when it is necessary to prioritize the importance of suppliers or when it is necessary to verify the accuracy of information before final inclusion in the Framework [18].

If the value of a variable «Compliance» is 1, data on the value of cargo from a supplier is included in the Framework. Otherwise, it is not included (including temporarily, until circumstances arise that allow changing the parameter value from 0 to 1).

As an indicator determining the suitability of cargo from each supplier, a matrix with binary variables (Table 3) can be formed. If all cargo indicators meet the conditions (the general characteristics or other laboratory tests for a certain type of construction work), the variable takes the value 1, if at least one condition is not satisfied, the value 0.

This will allow us to take into account cases where the cargo (aggregate) from one supplier is not suitable for use on certain jobs, but can be used for other types of work.

Table 3

An example of a binary matrix of qualitative assumptions (mA)

g	i	R				
		1	2	3	4	5
1	1	1	1	1	1	1
1	2	0	0	1	1	1
2	3	1	1	1	1	1
2	4	1	1	1	1	1
2	6	1	1	1	1	1
3	3	1	1	0	0	1
3	4	1	1	1	1	1
3	5	0	1	1	1	1

To determine the list of suppliers (i) whose cargoes or aggregates (g) can be used for specific types of construction work (r), a binary matrix is formed from a technological scheme of synergy capabilities (mSC).

Visualization of the compilation and filling of the matrix for the technological scheme of synergistic capabilities (mSC) is presented in Table 4.

Table 4

Matrix of the technological scheme of synergistic capabilities (mSC)

r	g	j				
		1	2	3	4	5
1	1	1	1	1	1	1
1	2	1	1	1	1	1
1	3	1	1	1	1	1
1	4	1	1	1	1	1
1	6	1	1	1	1	1
2	2	0	1	0	0	1
2	3	0	1	0	0	1
2	4	0	1	0	0	1
2	5	0	1	0	0	1

The data from Table 4 make it possible to limit the flow patterns of goods along the internal routes of the Framework and take into account their additional processing at individual transshipment points.

To determine the transportation distance from the last leg of the transshipment point to each cluster in the analyzed section, a matrix of average vehicle (automobile) trips $at_{j,k}$ is created (Table 5).

Table 5

Matrix of automobile transportation distances (mAT)

j	k									
	1	2	3	4	5	6	7	8	9	10
1	$at_{1,1}$	$at_{1,2}$	$at_{1,3}$	$at_{1,4}$	$at_{1,5}$	-	-	-	-	-
2	-	-	-	-	-	$at_{2,6}$	$at_{2,7}$	$at_{2,8}$	$at_{2,9}$	$at_{2,10}$
3	$at_{3,1}$	$at_{3,2}$	$at_{3,3}$	-	-	-	-	-	-	-
4	-	-	-	$at_{4,4}$	$at_{4,5}$	$at_{4,6}$	$at_{4,7}$	-	-	-
5	-	-	-	-	-	-	-	$at_{5,8}$	$at_{5,9}$	$at_{5,10}$
6	$at_{6,1}$	$at_{6,2}$	$at_{6,3}$	$at_{6,4}$	$at_{6,5}$	$at_{6,6}$	$at_{6,7}$	$at_{6,8}$	$at_{6,9}$	$at_{6,10}$

In cases where different combinations of additional cargo transshipments are provided at transshipment points according to the type of work, the target function outputs homogeneous goods (aggregates) and supplies from different transshipment locations to oncoming traffic to the same cluster. The absence of an automobile vehicle transportation distance in the mAT matrix eliminates the possibility of deliveries along this route. This condition ensures transparency of the technology for a developed transport and logistics scheme, eliminating the formation of counter-supplies.

The rule of preventing the formation of counter-supplies must be observed for transshipment points of the same types of mainline transport (water – automobile, railway – automobile).

If a supplier is included in the list of suppliers, it has the possibility of delivery by road only. In this case, the distance matrix (mAT) for all suppliers must indicate the distance of road transportation to each of the clusters.

Based on the distance of automobile transportation, costs with the variable $d_{j,k} = f(at_{j,k})$ are determined.

Regardless of the obvious attractiveness of terms of delivery from a particular supplier, it is necessary to create a stock matrix for all suppliers (and the volume of inventory of a particular cargo is indicated in a commercial offer, including indications of the seasons for potential delivery). This is necessary in order to rank the list of suppliers, taking into account a transition from conditions with maximum attractiveness to those with minimum inventory volumes of goods or aggregates. An example of a supplier inventory matrix that takes into account the maximum capabilities of suppliers for each cargo for their use within the framework is presented in Table 6. In this case, the variable $si_{i,g}$ reflects the amount of cargo stock «g» at the supplier «i» (in tons).

Table 6

Supplier Inventory Matrix (mSI)

i	g					
	1	**2**	**3**	**4**	**5**	**6**
1	$si_{1,1}$	-	-	-	$si_{1,5}$	-
2	$si_{2,1}$	-	$si_{2,3}$	-	-	$si_{2,6}$
3	$si_{3,1}$	$si_{3,2}$	-	$si_{3,4}$	-	-
4	-	$si_{4,2}$	$si_{4,3}$	-	$si_{4,5}$	-
5	-	-	$si_{5,3}$	-	-	-
6	-	si	-	-	-	-

The missing parameter in the supplier's inventory limit should been accepted like as not being a limiting factor, as the supplier's inventory exceeds the required amount for this cargo throughout the Framework.

Results

Based on the ranking of suppliers, taking into account the volume of cargo stocks and the attractiveness of delivery conditions, a final matrix is formed. It indicates the volume of goods from each supplier delivered to each of the framework clusters for specific types of construction works. An example of the final matrix of required materials (goods and aggregates) is presented in Table 7. In this instance, the variable $ga_{r,g,k}$ represents the volume of cargo «g» (goods and aggregates) in tons which delivered to cluster «k» for the purpose of construction work type «r».

Table 7

Matrix of required materials (goods and aggregates) (mGA)

r	g	k									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	**1**	$ga_{1,1,1}$	$ga_{1,1,2}$	$ga_{1,1,3}$	$ga_{1,1,4}$	$ga_{1,1,5}$	$ga_{1,1,6}$	$ga_{1,1,7}$	$ga_{1,1,8}$	$ga_{1,1,9}$	$ga_{1,1,10}$
1	**2**	$ga_{1,2,1}$	$ga_{1,2,2}$	$ga_{1,2,3}$	$ga_{1,2,4}$	$ga_{1,2,5}$	$ga_{1,2,6}$	$ga_{1,2,7}$	$ga_{1,2,8}$	$ga_{1,2,9}$	$ga_{1,2,10}$
1	**3**	$ga_{1,3,1}$	$ga_{1,3,2}$	$ga_{1,3,3}$	$ga_{1,3,4}$	$ga_{1,3,5}$	$ga_{1,3,6}$	$ga_{1,3,7}$	$ga_{1,3,8}$	$ga_{1,3,9}$	$ga_{1,3,10}$
1	**4**	$ga_{1,4,1}$	$ga_{1,4,2}$	$ga_{1,4,3}$	$ga_{1,4,4}$	$ga_{1,4,5}$	$ga_{1,4,6}$	$ga_{1,4,7}$	$ga_{1,4,8}$	$ga_{1,4,9}$	$ga_{1,4,10}$
1	**6**	$ga_{1,6,1}$	$ga_{1,6,2}$	$ga_{1,6,3}$	$ga_{1,6,4}$	$ga_{1,6,5}$	$ga_{1,6,6}$	$ga_{1,6,7}$	$ga_{1,6,8}$	$ga_{1,6,9}$	$ga_{1,6,10}$
2	**2**	$ga_{2,2,1}$	$ga_{2,2,2}$	$ga_{2,2,3}$	$ga_{2,2,4}$	$ga_{2,2,5}$	$ga_{2,2,6}$	$ga_{2,2,7}$	$ga_{2,2,8}$	$ga_{2,2,9}$	$ga_{2,2,10}$
2	**3**	$ga_{2,3,1}$	$ga_{2,3,2}$	$ga_{2,3,3}$	$ga_{2,3,4}$	$ga_{2,3,5}$	$ga_{2,3,6}$	$ga_{2,3,7}$	$ga_{2,3,8}$	$ga_{2,3,9}$	$ga_{2,3,10}$
2	**4**	$ga_{2,4,1}$	$ga_{2,4,2}$	$ga_{2,4,3}$	$ga_{2,4,4}$	$ga_{2,4,5}$	$ga_{2,4,6}$	$ga_{2,4,7}$	$ga_{2,4,8}$	$ga_{2,4,9}$	$ga_{2,4,10}$
2	**5**	$ga_{2,5,1}$	$ga_{2,5,2}$	$ga_{2,5,3}$	$ga_{2,5,4}$	$ga_{2,5,5}$	$ga_{2,5,6}$	$ga_{2,5,7}$	$ga_{2,5,8}$	$ga_{2,5,9}$	$ga_{2,5,10}$
…	**…**	…	…	…	…	…	…	…	…	…	…

Therefore, the supply of goods (aggregates) in quantities specified in the matrix (mGA) is a target condition for the transport and logistics scheme.

In order to provide a comprehensive presentation of the results, it is necessary to take into account additional parameters, including, on the one hand, a variable representing the maximum capacity of transshipment points $\boldsymbol{capj}$ [$\boldsymbol{J}$], and, on the other hand, the cost of transporting one ton of cargo per kilometer by road using vehicles.

Additionally, the total cost should include the possible cost of additional technological processing of goods (aggregates) at transshipment points $mProc$ (the method and cost of processing for each type of assembly will vary). For a clear comparison, each processing cost variable could be presented in a matrix format $mProc[(J+I)\times R]$.

After forming the initial data for the task, a set of limiting conditions is compiled (see equation 2):

$$\begin{cases} \text{mGA} \le \{\text{m}V \cap \text{mA} \cap \text{mSC}\} \\ \text{mSI} \ge \{\text{mX}\} \\ \boldsymbol{capj} \ \ge \{\text{mV} \cap \text{mSC}\} \\ \text{mV} \ge 0 \end{cases} \tag{2}$$

All constraints mean that data must comply with the requirements of construction sites and take into account the capabilities of each supplier. Furthermore, the capacities of each transshipment point must be observed in the Framework.

The search for a solution reduces to solving a linear programming problem, and can be found using any appropriate method, including Solver tools from MS Excel add-ons.

Structuring the task in spreadsheets allows solving a number of practical issues by correcting the source data. These practical issues may include:

– tasks related to the initial assessment of the viability of opening or closing additional transfer points;

– tasks of increasing the capacity of individual cargo and other facilities;

– possibility of using multimodal communication,

– etc

With sufficient skills in programming, the algorithm for finding optimal solutions can be implemented using Python programming code, accessing arrays in MS Excel spreadsheets.

Conclusions

Based on the Framework, relevant parties can determine not only the goal of reducing costs associated with transporting construction materials but the most suitable locations for auxiliary structures such as temporary cargo yards and marinas [19] which can be used as transshipment point. Such decisions also impact the final estimate of the cost of constructing the facilities.

The ordering of proposals from the most attractive to the least attractive for the supply of goods (aggregates) from suppliers to each transshipment point in all clusters of the construction site will allow for rational decisions to be made in the development of a plan to provide the facility with building materials.

Rational spending of budget funds will allow financing a larger number of projects that are strategically important for the development of the state.

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МЕТОД ПОИСКА РАЦИОНАЛЬНЫХ РЕШЕНИЙ В ЛОГИСТИКЕ СНАБЖЕНИЯ СТРОИТЕЛЬНЫМИ МАТЕРИАЛАМИ ПРОТЯЖЕННЫХ МАГИСТРАЛЬНЫХ ОБЪЕКТОВ

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Аннотация
В условиях реализации масштабных строительных и реконструкционных объектов важно обоснованно подходить к выбору не только поставщиков, но и способу транспортировки, пунктов перевалки груза и складов для хранения. Конкретным решениям должен предшествовать грамотный анализ информации о самих поставщиках, характеристиках реализуемых материалов, мощности перегрузочной инфраструктуры, находящейся в зоне тяготения к объекту строительства, а также информация о потенциальном размещении временных вспомогательных объектов, таких как: временные грузовые дворы и временные пристани. В статье представлен метод поиска рациональных решений, на основании которых может быть сформирована транспортно-логистическая схема снабжения протяженных строительных объектов материалами с учетом их стоимости, уровня запасов у поставщиков и минимальной транспортной составляющей в 1 тонне груза в точке потребления. К таким строительным объектам могут быть отнесены автомобильные или железнодорожные магистрали, не имеющие на этапе строительства устойчивых маршрутов подвоза материалов. Классические методы решения транспортной задачи не могут быть применены в условиях большой вариативности, поэтому предлагаемые решения особенно актуальны при ранжировании условий поставки различных материалов от большого количества поставщиков. К преимуществам предлагаемых решений относится возможность выполнения расчета в любом программно-вычислительном комплексе, а прозрачность описания методики расчета позволяет автоматизировать вычислительные процессы на любом языке программирования.

Ключевые слова: *снабжение строительных объектов, матрица, логистика строительных материалов, строительство транспортных объектов, транспортно-логистическая схема.*

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